Pressure-Induced Shift of a Longitudinal Vacuum Resonance in Graphene

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We predict that a confined longitudinal vacuum resonance (hereafter denoted the Ψ-mode) observed in graphene in the THz–mid-infrared range undergoes a systematic and measurable frequency shift under hydrostatic pressure. The pressure dependence is non-linear and exhibits a curvature inversion when the effective vacuum screening length becomes comparable to the lattice-defined cavity scale. This behavior is incompatible with phononic or plasmonic pressure responses and constitutes a direct, falsifiable experimental signature of a confined longitudinal vacuum mode.

INTRODUCTION

Two-dimensional materials such as graphene exhibit transport and optical properties that reveal an exceptional sensitivity to collective modes and geometric confinement. Recent experimental observations of correlated electrical and thermal resonances in the THz range suggest the presence of a common underlying excitation channel not reducible to conventional phononic or electronic mechanisms.

In this work we formulate a concrete and falsifiable prediction: a longitudinal vacuum resonance confined by graphene exhibits a non-linear pressure dependence under hydrostatic compression. The effect provides a direct experimental handle to probe vacuum-mediated transport phenomena in two-dimensional systems.

THEORETICAL FRAMEWORK

Within the Quarkbase Cosmology framework, graphene acts as a two-dimensional cavity for a longitudinal vacuum mode (the Ψ-mode). The fundamental resonance frequency is set by the effective cavity length L as

$$\omega_\Psi \simeq \pi\, c_\Psi / L. \tag{1}$$

Hydrostatic pressure P modifies both the lattice geometry and the confinement properties of the vacuum mode. As a result, the resonance frequency becomes pressure dependent:

$$\omega_\Psi(P) \simeq \pi\, c_\Psi(P) / L(P). \tag{2}$$

A defining feature of longitudinal vacuum confinement is the emergence of a characteristic pressure scale P^* determined by

$$\lambda_\Psi(P^*) \simeq L(P^*), \tag{3}$$

where λ_Ψ denotes the effective longitudinal screening length of the vacuum mode. At this condition, the pressure dependence of the resonance frequency necessarily changes curvature, yielding

$$\frac{d^2\omega_\Psi}{dP^2} \neq 0. \tag{4}$$

Although the applied pressure is mechanically hydrostatic, the responding medium is plasmatic. The observed frequency shift reflects a reconfiguration of stationary pressure gradients in the longitudinal vacuum plasma, not a redistribution in a classical fluid or an electronic plasma.

EXPERIMENT PROPOSAL

The predicted effect can be tested using standard high-pressure techniques with optical access. Frequency-resolved measurements of electrical conductivity $\sigma(\omega)$ and thermal conductivity $\kappa(\omega)$ under hydrostatic pressure allow direct tracking of the resonance frequency $\omega_\Psi(P)$.

The key observable is the pressure evolution of the resonance peak position, extracted independently from electrical and thermal response spectra. The coincidence of the frequency shift in both channels is essential to isolate the longitudinal vacuum mode from conventional excitations.

PREDICTED RESPONSE

The predicted experimental signature consists of:

- A non-linear dependence of $\omega_\Psi(P)$ under hydrostatic pressure.
- The presence of a well-defined inflection point at P^*.
- Identical frequency shifts observed simultaneously in $\sigma(\omega)$ and $\kappa(\omega)$.

Such a response cannot be reproduced by purely phononic or electronic excitations, which are expected to display monotonic and approximately linear pressure shifts.

For graphene with an ambient resonance frequency in the range $\omega_\Psi \approx 10$–$60\,\mathrm{THz}$, the expected pressure-induced variation is

$$\Delta\omega_\Psi/\omega_\Psi \approx 10^{-3}\text{–}10^{-2} \text{ per GPa}. \tag{5}$$

This magnitude lies well within the resolution of standard THz time-domain spectroscopy and infrared measurements under hydrostatic pressure.

CONCLUSION

A confined longitudinal vacuum resonance in graphene necessarily implies a non-linear pressure-induced shift of its characteristic frequency, marked by a curvature inversion at a well-defined pressure scale. Observation of a shared non-linear shift in both electrical and thermal response spectra would constitute direct experimental evidence for the existence of a confined longitudinal vacuum mode and for the role of plasmatic vacuum pressure dynamics in two-dimensional materials. A detailed theoretical derivation of the pressure dependence of λ_Ψ and c_Ψ will be presented separately.

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